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Experimental investigation into the mechanical properties of metal anodes in lithium-ion batteries

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ABSTRACT

In the search for high-capacity lithium-ion batteries, metal anodes, such as silicon and aluminum among others, have emerged possessing a theoretical specific charge capacity significantly greater than their conventional graphite counterpart. In spite of their high capacity, metal anodes based lithium-ion batteries have shown poor structural integrity and cycle life, which has been the bottleneck to the large scale implementation of these kinds of batteries. This issue arises from the large dimensional changes that accompany the phase transformations during lithiation/delithiation (alloying/dealloying with/from lithium) in metal anodes. The evolution of mechanical behavior during phase transformation determines the deformation and fracture behavior and also affects the kinetic processes involved in phase transformation. Thus, understanding the evolution of mechanical properties during electrochemical phase transformation and its dependence on microstructure is necessary in mechanical reliability and electrochemical performance analysis. In this article, we report an experimental investigation into the evolution of mechanical properties in select metal anodes in which phase transformations result in contrasting changes in microstructure and mechanical properties. The metal anodes studied consisted of brittle Si, which transforms to ductile lithiated Li_xSi and ductile Al, which transforms to brittle lithiated Li_xAl . Uniaxial tensile tests and nanoindentation were utilized to investigate the mechanical properties, and X-ray diffraction used to examine the structural evolution of Si and Al anodes during lithiation. Fractographic studies were performed in a scanning electron microscope to elucidate the fracture mechanisms. The effect of the transition in mechanics of metal anodes on the kinetic processes during phase transformation in Si and Al is discussed.